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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 :
G01F 1/32, 15/08, 1/74
G01F 1/66

A1

(11) International Publication Number: WO 91/08444

(43) International Publication Date: 13 June 1991 (13.06.91)

(21) International Application Number: PCT/GB90/01847

(22) International Filing Date: 28 November 1990 (28.11.90)

(30) Priority data:
8927195.1 1 December 1989 (01.12.89) GB

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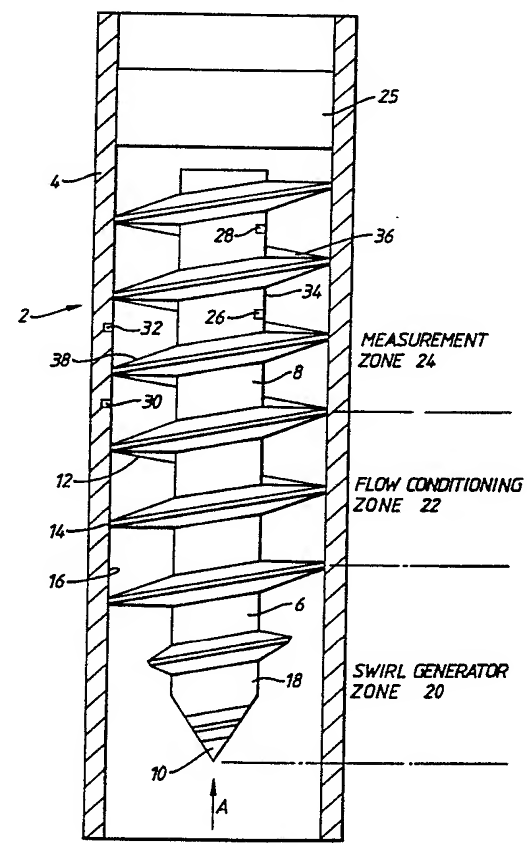
(81) Designated States: AT, AT (European patent), AU, BB, BE (European patent), BF (OAPI patent), BG, BJ (OAPI patent), BR, CA, CF (OAPI patent), CG (OAPI patent), CH, CH (European patent), CM (OAPI patent), DE, DE (European patent), DK, DK (European patent), ES, ES (European patent), FI, FR (European patent), GA (OAPI patent), GB, GB (European patent), GR (European patent), HU, IT (European patent), JP, KP, KR, LK, LU, LU (European patent), MC, MG, ML (OAPI patent), MR (OAPI patent), MW, NL, NL (European patent), NO, RO, SD, SE, SE (European patent), SN (OAPI patent), SU, TD (OAPI patent), TG (OAPI patent), US.

Published
With international search report.

(54) Title: MEASURING FLOW CHARACTERISTICS OF FLUID STREAMS

(57) Abstract

A flowmeter for measuring at least one flow characteristic of a fluid stream flowing through a pipe, the flowmeter comprising a pipe, a body which is located in the pipe and is adapted to induce a swirling flow in the fluid stream, pulse emitting means for emitting energy pulses into the swirling flow, pulse receiving means for receiving the energy pulses transmitted through the swirling flow and processing means for processing signals from the pulse emitting means and pulse receiving means thereby to determine at least one flow characteristic of the fluid stream. The invention also relates to a method of measuring at least one flow characteristic of a fluid stream flowing through a pipe.



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"MEASURING FLOW CHARACTERISTICS OF FLUID STREAMS".

The present invention relates to a flowmeter for measuring at least one flow characteristic of a fluid stream flowing through a pipe and to a method of measuring at least one flow characteristic of a fluid stream flowing through a pipe.

Two and three phase gas/liquid flows occur in a variety of flow regimes in many different industrial processes. The desired flow regime is application specific. However, the majority of such industrial processes have bubbly, slug or annular flow regimes. Multiphase flow regimes frequently occur in the oil industry, for example in unprocessed well fluids and gas/condensate pipe lines; in the chemical industry, for example in mixing, cryogenic, distillation and heat transfer processes; and in the electricity generating industry, for example in conventional steam-powered electricity generators. In many applications, the equipment is designed so that multiphase flow does not occur. In some cases, this design criterion is necessary because the technology required to process a multiphase fluid is not available.

Currently, a great deal of research and development is being carried out in areas such as multiphase pumping, much of which research and development is geared to the needs of the oil industry. The oil company Texaco has developed a multiphase meter for use in the oil industry, such meter being described in the journal "Offshore Engineer", dated March 1989, pages 31 and 32. In the Texaco multiphase meter, an incoming gas/liquid flow is gravitationally separated into a gas stream and a liquid stream and each stream is measured individually. The streams are then combined for three phase flow to a platform or the shore. Separation is achieved

using an inclined separator thereby achieving gravity separation of the liquid stream from the gas stream. The Texaco multiphase meter suffers from the disadvantages, inter alia, of high cost and large size. A multiphase flowmeter has also been proposed by the National Engineering Laboratory (NEL) which similarly separates a gas stream from a liquid stream and then each stream is analysed separately. The NEL multiphase flowmeter suffers from the disadvantage, inter alia, of a susceptability to variations in the flow regime.

The present invention aims to provide a flowmeter which can measure flow characteristics of a fluid stream which can at least partially alleviate the problems of the prior art.

The present invention provides a flowmeter for measuring at least one flow characteristic of a fluid stream flowing through a pipe, the flowmeter comprising a pipe, a body which is located in the pipe and is adapted to induce a swirling flow in the fluid stream, pulse emitting means for emitting energy pulses into the swirling flow, pulse receiving means for receiving the energy pulses transmitted through the swirling flow and processing means for processing signals from the pulse emitting means and pulse receiving means thereby to determine at least one flow characteristic of the fluid stream.

The present invention also provides a method of measuring at least one flow characteristic of a fluid stream flowing through a pipe, the method comprising the steps of:-

(a) inducing a swirling flow in the fluid stream in the pipe;

(b) emitting energy pulses from pulse emitting means into the swirling flow;

(c) receiving the energy pulses, which have been transmitted through the swirling flow by pulse receiving means; and

(d) processing signals from the pulse emitting means and the pulse receiving means thereby to determine at least one flow characteristic of the fluid stream.

Embodiments of the present invention will now be described by way of example only with reference to the accompanying drawings, in which:-

Figure 1 is a part sectional plan view of the mechanical portion of a flowmeter in accordance with a first embodiment of the present invention;

Figure 2 is a schematic diagram of the mechanical portion of Figure 1 in combination with an electronic control system of the flowmeter according to the first embodiment of the present invention;

Figure 3 illustrates in detail a part of the mechanical portion of Figure 1 in operation and wherein a two phase fluid stream is being measured;

Figure 4 is a diagram similar to Figure 3 and illustrates the mechanical portion of a flowmeter in accordance with a second embodiment of the present invention in operation and wherein a three phase fluid stream is being measured;

Figure 5 is a part sectional plan view similar to Figure 1 of the mechanical portion of a flowmeter in accordance with a third embodiment of the present invention; and

Figure 6 is a part sectional plan view similar to Figure 1 of the mechanical portion of a flowmeter in accordance with a fourth embodiment of the present invention.

Referring to Figure 1, there is shown a mechanical portion of a flowmeter in accordance with a first embodiment

of the present invention. The flowmeter 2 comprises a straight length of cylindrical pipe 4, for example of metal. A swirl inducing internal centrebody 6 is located in the pipe 4. The internal centrebody 6 includes a substantially cylindrical central portion 8 which is disposed along the axis of the pipe 4 and reduces to a point 10 at the upstream end thereof. A helical portion 12 of the internal centrebody 6 surrounds the central portion 8 and is integral therewith. The outer helical edge 14 of the helical portion 12 engages and is fixedly attached to the inner surface 16 of the pipe 4 whereby the internal centrebody 6 is securely fixed in the pipe 4 without any freedom of movement. The helical edge 14 of the helical portion 12 may be fixed to the inner surface 16 of the pipe 4 by welding. In the embodiment illustrated in Figure 1, the internal centrebody 6 resembles a screw having a single start thread, with the screw pointing in the upstream direction.

The internal centrebody 6 is adapted to induce a swirling flow in a fluid stream flowing along the pipe 4. The fluid direction is indicated by arrow A in Figure 1 The upstream end 18 of the internal centrebody 6 constitutes a swirl generator zone 20 of the flowmeter 2. When a fluid stream enters the swirl generator zone 20, the fluid stream is urged radially outwardly by the central portion 8 of the internal centrebody 6 which thus applies a centrifugal force to the fluid stream which develops a swirling flow field. The swirling flow field thus developed has the characteristics that the axis of rotation of the fluid and the axis of the pipe through which the fluid flows are coincident and the swirl is a feature of the "bulk" of the fluid flow and as such is not a local flow disturbance i.e. all the fluid rotates around the axis of rotation of the fluid flow. The swirling flow field is in the form of a helical non-turbulent flow. A consequence of the development of a swirling flow field is that a multiphase fluid separates into its individual phase components due to the difference in density between the

phases. This results in the swirling flow being a series of coaxial helical laminar flows. The least dense phase migrates towards the central portion 8 of the internal centrebody 6 whereas the most dense phase flows radially outwardly towards the inner surface 16 of the pipe 4. Thus this causes centrifugal separation of the multiphase fluid stream into a plurality of distinct phases. The separated fluid stream then passes to a flow conditioning zone 22 in which the separation of the different phases is made more uniform and then the separated fluid stream flows to a measurement zone 24 wherein the intensely swirling flow field of the separated phases is measured, as is described hereinbelow. The development of the swirling flow is not significantly influenced by the upstream or downstream flow regime of the fluid stream. A flow straightener 25, of any typical known construction, is located downstream of the measurement zone 24 and acts to reduce the swirl of the flow of the fluid.

At the measurement zone 24 are disposed two pairs of ultrasonic acoustic transducers 26,28 and 30,32. The first pair of ultrasonic transducers 26,28 is mounted on the outer surface 34 of the central portion 8 and the ultrasonic transducers 26,28 are separated in a direction along the length of the central portion 8 by the helical portion 12, and in particular by one thread 36 of the helical portion 12. Alternatively, the transducers 26,28 may be separated by more than one thread provided that sufficient signal discrimination can be obtained. The ultrasonic transducers 26,28 are adapted to transmit ultrasonic pulses through an inner phase of the centrifugally separated fluid stream. The second pair of ultrasonic transducers 30,32 is mounted on the inner surface 16 of the pipe 4 and the ultrasonic transducers 30,32 are separated in a direction along the length of the pipe 4 by the helical portion 12, and in particular by one thread 38 of the helical portion 12. Alternatively, the transducers 30,32 may be separated by more than one thread provided that sufficient

signal discrimination can be obtained. The ultrasonic transducers 30,32 are adapted to transmit ultrasonic pulses through an outer phase of the centrifugally separated fluid stream.

Figure 2 shows schematically the mechanical portion shown in Figure 1 in combination with an electronic control system 40 therefor which includes data acquisition/data processing hardware and software. The control system 40 includes a power supply 42 which powers a processing means 41 for processing signals from the two pairs of ultrasonic transducers 26,28 and 30,32 thereby to determine at least one flow characteristic of the fluid stream. The processing means 41 comprises a data acquisition module 44 which acquires data from the ultrasonic transducers 26,28 and 30,32, a data analysis module 46 which analyses the data and an output device 48 which outputs the analysed data and the measured flow characteristics of the fluid stream. The two pairs of transducers 26,28 and 30,32 are connected to the data acquisition module 44 by respective pairs of connectors 50,52 and 54,56. The data acquisition module 44 triggers the transducers into emitting pulses, monitors when pulses are received, and determines the time between pulse emission and reception, which time determination is employed to measure the characteristics of the fluid stream in the manner described below. The data acquisition module 44 and the data analysis module 46 are operated under software control.

The operation of the flowmeter shown in Figures 1 and 2 will now be described with reference to Figure 3. Figure 3 shows in greater detail a part of the pipe 4/internal centrebody 6 construction wherein a two phase fluid, e.g. oil and water, or oil and gas, has been separated by the internal centre body 6 into two separate phases 58,60 with an interface 62 therebetween. It will be seen that in the measurement zone 24 the two phase fluid is separated into two separate phases

58,60 which form two concentric helixes as shown in Figure 3. The inner helix consists of the less dense phase 58 e.g. oil and the outer helix consists of the more dense phase 60, e.g. water. The two pairs of transducers 26,28 and 30,32 are each associated with a respective phase, the inner pair of transducers 26, 28 acting on the inner phase 58 and the outer pair of transducers 30,32 acting on the outer phase 60.

Each pair of transducers is controlled by the processing means and the signals issuing therefrom are acquired and analysed by the processing means to calculate:

(a) the volumetric flow rate of each phase;
(b) the mean velocity of each phase;
(c) the acoustic velocity of each phase;
(d) the position of the interface between the phases; and
(e) the mean density of each phase.

The two pairs of transducers, 26,28 and 30,32 operate simultaneously in such pairs but the two pairs transmit at different ultrasonic frequencies, preferably in broad bandwidths, thus ensuring adequate discrimination between the signals of the two pairs. For ease of description, each of transducers 26,28, 30 and 32 is also represented by a respective letter A, D, B, C. Considering transducers A and D of the first pair, a pulse of ultrasonic energy is emitted from transducer A and the pulse of ultrasonic energy is then:

1. Reflected from the interface 62 between then two phases 58 and 60 and is detected back at transducer A after T_{AA} seconds.

2. Detected at transducer D after T_{AD} seconds, the pulse having been transmitted in a helical path through the inner phase 58. This detection is used to trigger a second pulse of ultrasonic energy to be emitted from transducer D. This pulse is in turn:

3. Reflected from the interface 62 between the two phases 58 and 60 and detected back at transducer D after T_{DD} seconds.

4. Detected at transducer A after T_{DA} seconds, the pulse having been transmitted in a helical path through the inner phase 58.

These four time measurements T_{AA}, T_{AD}, T_{DD} and T_{DA} together with a knowledge of the spatial position of the transducers A and D and the internal geometry of the flowmeter 2, are sufficient to enable calculation of the volumetric flow rate of the first phase; the mean velocity of the first phase, the acoustic velocity of the first phase and the position of the interface relative to the central portion 8. The calculation of these parameters is carried out as follows:

From the four time measurements described hereinabove,

$$T_{AA} = \frac{2X_1}{C_1} \quad \text{and} \quad T_{AD} = \frac{L}{C_1 + U_1}$$

where T = elapsed time between the respective transducers
X_1 = distance to interface of the inner phase
C_1 = acoustic velocity in the inner phase
L = helical path length between the respective transducers (which can be measured)
U_1 = mean velocity of the inner phase

Similarly,

$$T_{DD} = \frac{2X_1}{C_1} \quad \text{and} \quad T_{DA} = \frac{L}{C_1 - U_1}$$

From which are obtained

The acoustic velocity in the given phase, $C_1 = \frac{1}{2}\left[\frac{L}{T_{AD}} + \frac{L}{T_{DA}}\right]$

and the mean velocity of the inner phase $U_1 = \frac{1}{2}\left[\frac{L}{T_{AD}} - \frac{L}{T_{DA}}\right]$

Therefore, the thickness of the inner phase at transducer A, i.e. $X_1 = \frac{C_1 T_{AA}}{2}$

and

the thickness of the inner phase at transducer D, i.e. $X_1 = \frac{C_1 T_{DD}}{2}$

Knowing the internal geometry of the flowmeter (represented by f (geometry) which is representative of the cross-sectional area of the helical fluid stream) it is possible to calculate the volumetric flowrate (Q) of the first phase, which is

$Q = f(\text{geometry}, X_1) \times U_1$

If the attenuation of the wave reflected at the interface is measured, then it is possible to calculate the mean density of the phase and hence calculate the mass flowrate of the phase. This may be done in the following manner.

It is known for example from an article entitled "Ultrasonic density measurement for process control" by J.M. Hale in Ultrasonics, 1988, Vol. 26, pp. 356 - 357, that changes in acoustic impedance are directly proportional to changes in pulse amplitude.

Now, for a given material

$Z = \rho c$ where Z = acoustic impedence in the material
ρ = density of the material
c = acoustic velocity in the material

and for an unknown fluid x

$Zx = Z_R + \delta_Z$, where Z_R = the known acoustic impedance in a reference fluid such as water

δ_Z = the difference in impedance between the fluid x and the reference fluid, obtained by analysis of the transmitted and reflected pulse amplitudes.

Thus, for fluid x

$$\rho x = \frac{Z_R + \delta_Z}{Cx}$$

Since δ_z and Cx are known, ρx may be evaluated.

The mass flowrate is then given by $M = \rho Q$.

Thus the data acquisition module 44 and the data analysis module 46 are operated under software control to output values of the volumetric and mass flowrate of the inner phase, the mean velocity of the inner phase, the acoustic velocity of the inner phase, and the density of the inner phase and also the position of the interface between the two phases. The output is displayed or printed by the output device 48.

The second pair of transducers, namely transducers B and C, work in exactly the same manner as the first pair of transducers A and D, and enable the calculation of the same properties for the second phase.

The system disclosed can make frequent measurements of the various parameters of the phases and hence continuously monitor the flow of fluid through the flowmeter. If the flow rates are calculated for each phase, the flowrates can be summed to provide a total volumetric or mass flowrate.

A similar processing technique may be used for single phase flow.

The present invention can also be used to measure flow characteristics of three phase flow, this being illustrated in Figure 5. It will be seen that in three phase flow the multiphase fluid is centrifugally separated by the central portion 8 of the internal centrebody 6 in a manner similar to that described hereinabove. In the measurement zone 64 the fluid consists of a low density inner phase 66, an intermediate density middle phase 68 and a high density outer phase 70. The three phases 66,68 and 70 are in the form of concentric helixes. In the embodiment illustrated in Figure 5, the second pair of transducers 72,74 which is disposed in the inner surface of the pipe 4 is substantially opposite the first pair of transducers 76,78 which is disposed in the surface of the central portion 8.

The flow characteristics of the inner phase 66 and the outer phase 70 are determined as described hereinabove and the flow characteristics of the middle phase 68 can be calculated therefrom in conjunction with known geometric parameters of the flowmeter. The flowmeter of the present invention could additionally be modified to measure a multiphase flow having more than three phases.

In order to obtain a value of the volumetric flowrate of each phase only the measurement of time is required by employing ultrasonic transducers. In the preferred embodiment of the present invention, time may be measured with sufficient

accuracy to enable accurate results to be obtained and the apparatus does not require calibration. In addition, the flowmeter of the preferred embodiments can incorporate self-diagnostic circuits that utilise the National Physical Laboratories (NPL) national standard timing frequency.

In order to obtain a value of the density of each phase the acoustic impedance of the ultrasonic transmitter/receiver must be known or measured. In addition, a calibration with a reference fluid, which may be water, of known acoustic properties is required. This procedure should be performed in a well-controlled laboratory environment. Individual calibration factors, such as acoustic impedance and physical geometry data, are included in the signal processing software of the flowmeter thereby to ensure that a target accuracy of ± 5% is readily achieved.

Figure 6 illustrates a further embodiment of the present invention wherein the internal centrebody 80 has multi-start helical portions 82, the internal centrebody 80 being similarly disposed in a straight pipe 84 with the outer helical surfaces of the internal centrebody 80 being in contact with the inner surface 88 of the pipe 84.

Figure 7 illustrates a still further embodiment of the present invention wherein the internal centrebody 90 is disposed in a pipe 92 which incorporates a right-angled bend therein. The centrebody 90 is disposed in a straight part of the pipe 92 with the downstream end 94 of the centrebody 90 facing the bent part of the pipe 92. The helical portion 96 of the centrebody 90 has a diameter which is less than the internal diameter of the pipe 92 and the centrebody 90 is not fixed relative to the pipe 92. There is a small clearance 97 between the outer helical surface 98 and the internal surface 100 of the pipe 92. An elongate drive shaft 102 is connected to the downstream end 94 of the centrebody 90 and is co-axial

with the central portion 104 of the centrebody 90. The drive shaft 102 extends, in a sealed manner, through the circumferentially outer wall 106 of the bent part of the pipe 92 and is connected to a drive mechanism 108. The centrebody 90 defines a swirl generator zone 110, a flow conditioning zone 112 downstream thereof and a measurement zone 114 downstream thereof. A flow straightener 116 is disposed downstream of the centrebody 90.

In use, the centrebody 90 is rotated about its longitudinal axis by the drive mechanism 108 and this assists the separation of the multiphase fluid, flowing in direction A, into a plurality of discrete phases in the manner described hereinabove.

In alternative embodiments of the present invention, the fluid flow could enter the flowmeter tangentially rather than axially and the tangential flow would result in spiral paths of the separated phases. In addition, the transducers could be modified so as to measure the capacitance of the fluid phases or other electromagnetic properties.

The present invention has particular application in the oil industry and more particularly for use in measuring the flow of a multiphase fluid comprising gas, oil and water. The present invention can operate under a whole range of flow conditions, ranging from bubbly flow, wherein a small amount of gas is entrained as bubbles in the multiphase fluid, to slug flow wherein periodically the flow consists solely of gas and no liquid. The present invention can also operate with reverse flow of fluid. In the oil industry, for a single well slot the pipe would typically have an internal diameter of 4 to 6 inches which could be used for a well having a production of 2 1/2 thousand barrels per day but the diameter could if desired be considerably bigger, for example 36 inches in total diameter.

CLAIMS.

1. A flowmeter for measuring at least one flow characteristic of a fluid stream flowing through a pipe, the flowmeter comprising a pipe, a body which is located in the pipe and is adapted to induce a swirling flow in the fluid stream, pulse emitting means for emitting energy pulses into the swirling flow, pulse receiving means for receiving the energy pulses transmitted through the swirling flow and processing means for processing signals from the pulse emitting means and pulse receiving means thereby to determine at least one flow characteristic of the fluid stream.

2. A flowmeter according to claim 1 wherein the body includes a helical portion which is adapted to produce a helical swirling flow in the fluid stream.

3. A flowmeter according to claim 2 wherein the body further includes a central portion which is surrounded by the helical portion and which is adapted to urge the fluid stream radially outwardly therefrom thereby to permit centrifugal separation of a multiphase fluid stream into a plurality of distinct phases.

4. A flowmeter according to claim 3 wherein the body is elongate and is longitudinally disposed in the pipe.

5. A flowmeter according to claim 4 wherein the body is fixed relative to the pipe.

6. A flowmeter according to claim 3 wherein the body can rotate relative to the pipe and further comprising means for rotating the body.

7. A flowmeter according to any one of claims 3 to 6 wherein the pulse emitting means and the pulse receiving means comprise acoustic transducers.

8. A flowmeter according to claim 7 wherein the pulse transmitting means and the pulse receiving means comprise first and second pairs of acoustic transducers for emitting and receiving pulses of ultrasonic energy.

9. A flowmeter according to claim 8 wherein the first pair of the acoustic transducers is mounted on an outer surface of the central portion and the acoustic transducers of the first pair are separated in a direction along the length of the central portion by the helical portion, the first pair being adapted to transmit ultrasonic pulses through an inner phase of the centrifugally separated fluid stream.

10. A flowmeter according to claim 8 or claim 9 wherein the second pair of the acoustic transducers is mounted on the inner surface of the pipe and the acoustic transducers of the second pair are separated in a direction along the length of the pipe by the helical portion, the second pair being adapted to transmit ultrasonic pulses through an outer phase of the centrifugally separated fluid stream.

11. A flowmeter according to any one of claims 8 to 10 wherein at least one acoustic transducer of each pair is adapted to emit an acoustic pulse and to receive a reflected pulse which is reflected from an interface between two centrifugally separated phases.

12. A flowmeter according to claim 11 wherein each acoustic transducer of each pair is adapted to emit acoustic pulses which are detected by the other acoustic transducer of each pair.

13. A flowmeter according to any one of claims 8 to 12 wherein the processing means is adapted to process signals from the pulse emitting means and the pulse receiving means, the signals representing the transmission time of pulses

through at least one of the phases thereby to calculate at least one of the volumetric flowrate; the mean velocity and the acoustic velocity of the respective phase.

14. A flowmeter according to any one of claims 8 to 13 wherein the signal processing means is adapted to process signals from the pulse emitting means and the pulse receiving means representing attenuation of the pulses by at least one of the phases thereby to calculate at least one of the mean density and the mass flowrate of the respective phase.

15. A method of measuring at least one flow characteristic of a fluid stream flowing through a pipe, the method comprising the steps of:-

(a) inducing a swirling flow in the fluid stream in the pipe;

(b) emitting energy pulses from pulse emitting means into the swirling flow;

(c) receiving the energy pulses, which have been transmitted through the swirling flow, by pulse receiving means; and

(d) processing signals from the pulse emitting means and the pulse receiving means thereby to determine at least one flow characteristic of the fluid stream.

16. A method according to claim 15 wherein a helical swirling flow is induced in the fluid stream.

17. A method according to claim 15 or claim 16 wherein the fluid stream is a multiphase fluid stream comprising a plurality of phases and in the swirling flow the multiphase stream is centrifugally separated into a plurality of distinct phases.

18. A method according to claim 17 wherein the pulse emitting means and the pulse receiving means comprise acoustic transducers and the energy pulses are pulses of ultrasonic energy.

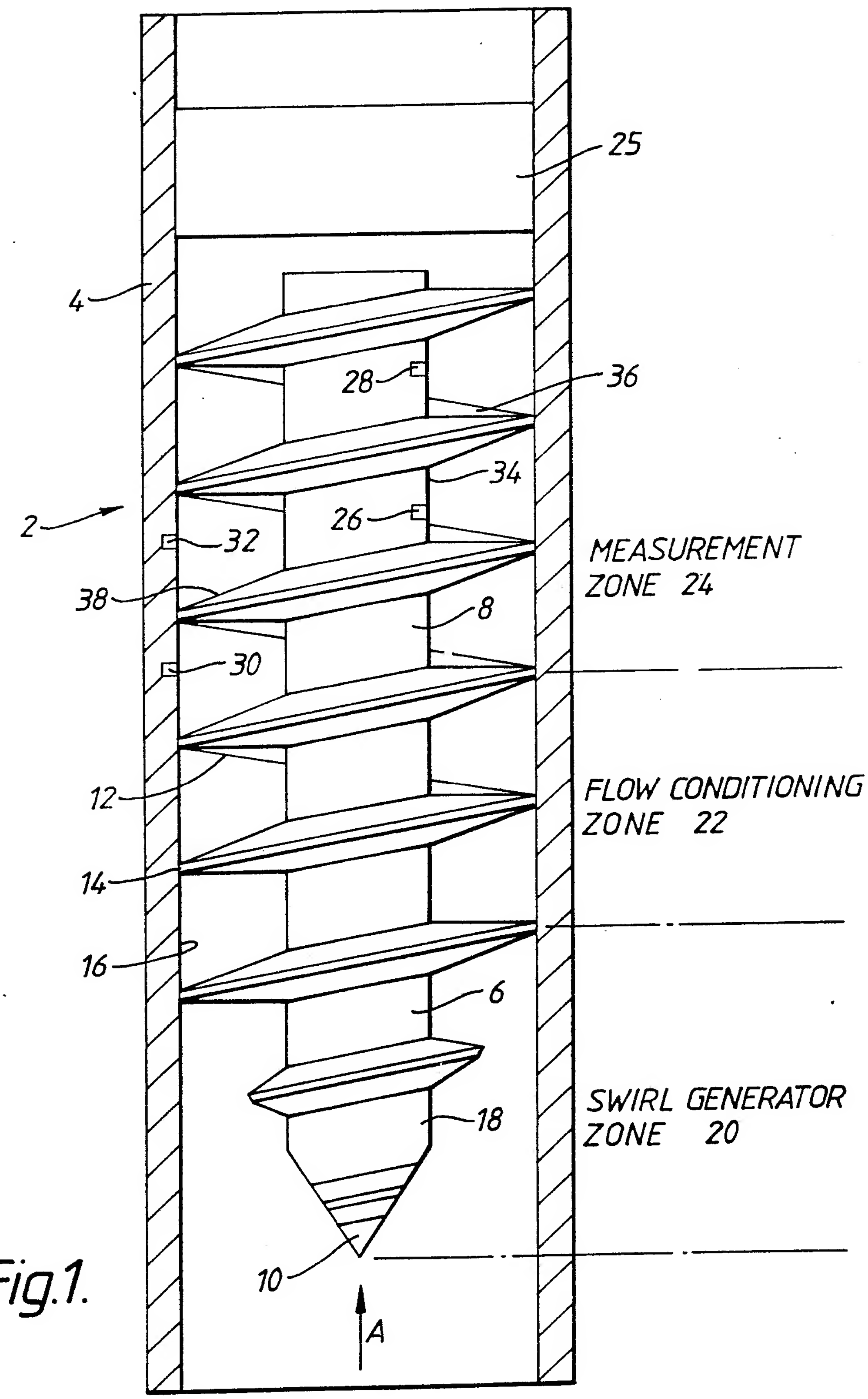
19. A method according to claim 18 wherein the acoustic transducers comprise first and second pairs thereof, each pair transmitting ultrasonic pulses through a respective phase.

20. A method according to claim 19 wherein at least one acoustic transducer of each pair emits an acoustic pulse and receives a reflected pulse which is reflected from an interface bewteen two centrifugally separated phases.

21. A method according to claim 19 wherein each acoustic transducer of each pair emits a signal which is detected by the other acoustic transducer of each pair.

22. A method according to any one of claims 17 to 21 wherein in processing step (d) signals representing the transmission time of pulses through at least one of the phases are processed thereby to calculate at least one of the volumetric flowrate; the mean velocity and the acoustic velocity of the respective phase.

23. A method according to any one of claims 17 to 22 wherein in processing step (d) signals representing attenuation of the pulses by at least one of the phases are processed thereby to calculate at least one of the density and the mass flowrate of the respective phase.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4
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34
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26
32
MEASUREMENT
ZONE 24
38
8
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FLOW CONDITIONING
ZONE 22
14
16
6
18
SWIRL GENERATOR
ZONE 20
10
A

Fig.1.

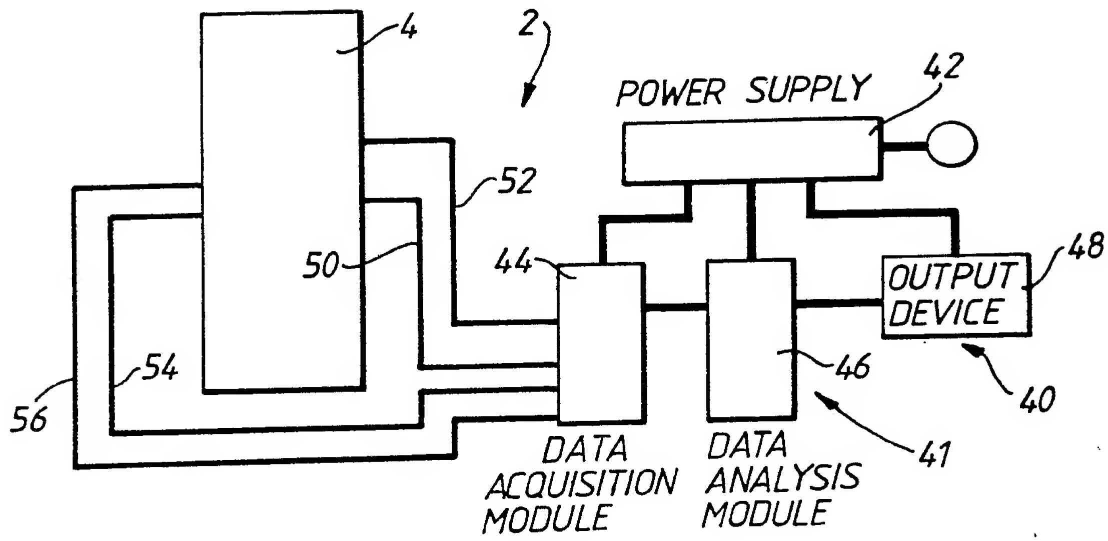


Fig.2.

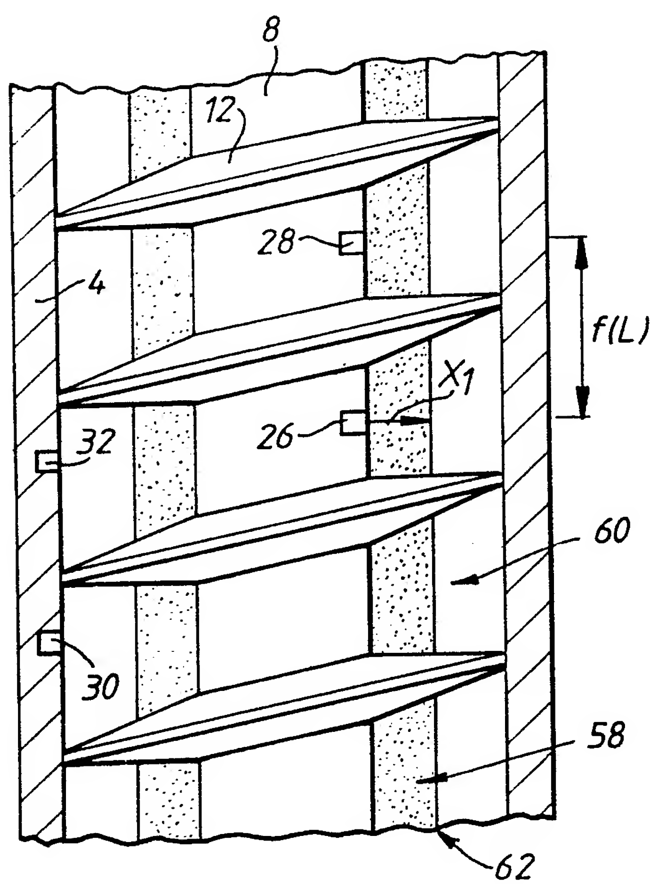


Fig.3.

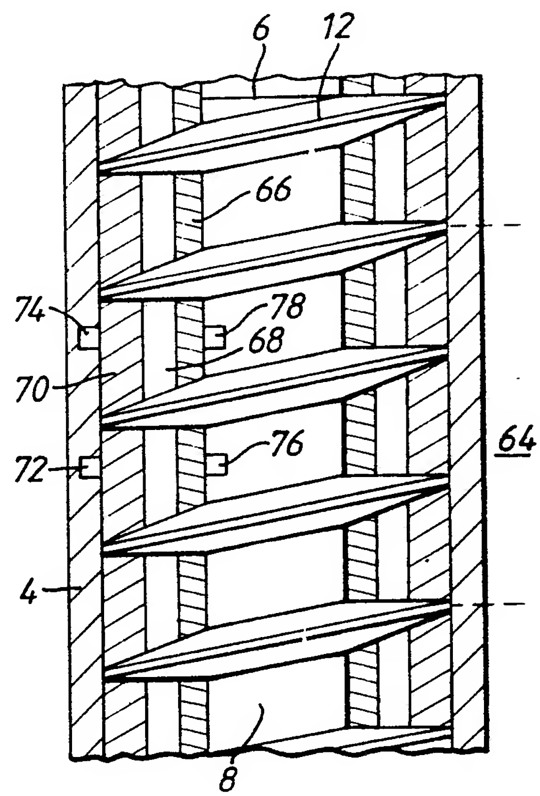
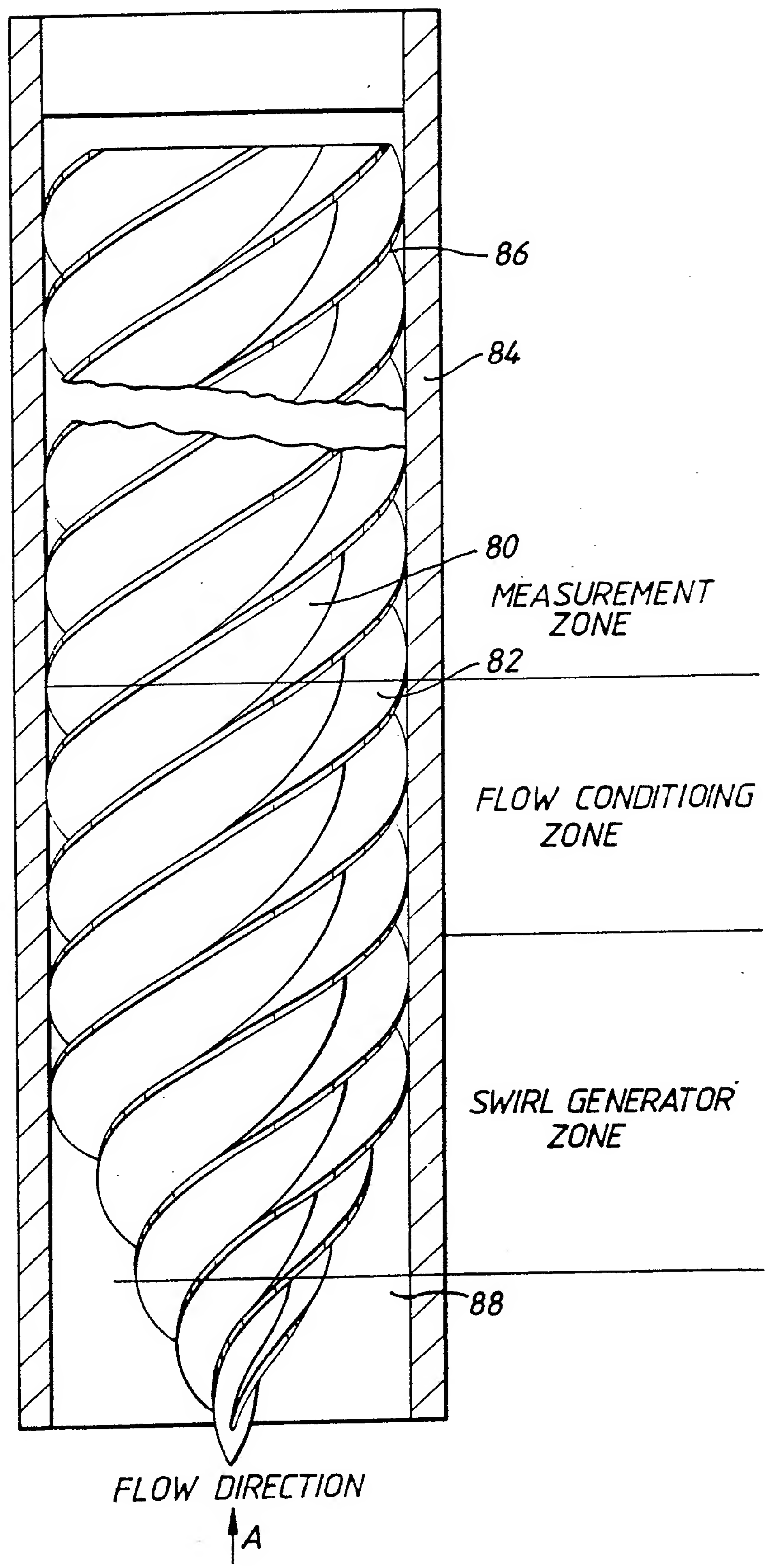


Fig.4.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FLOW CONDITIOING ZONE
SWIRL GENERATOR ZONE
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FLOW DIRECTION
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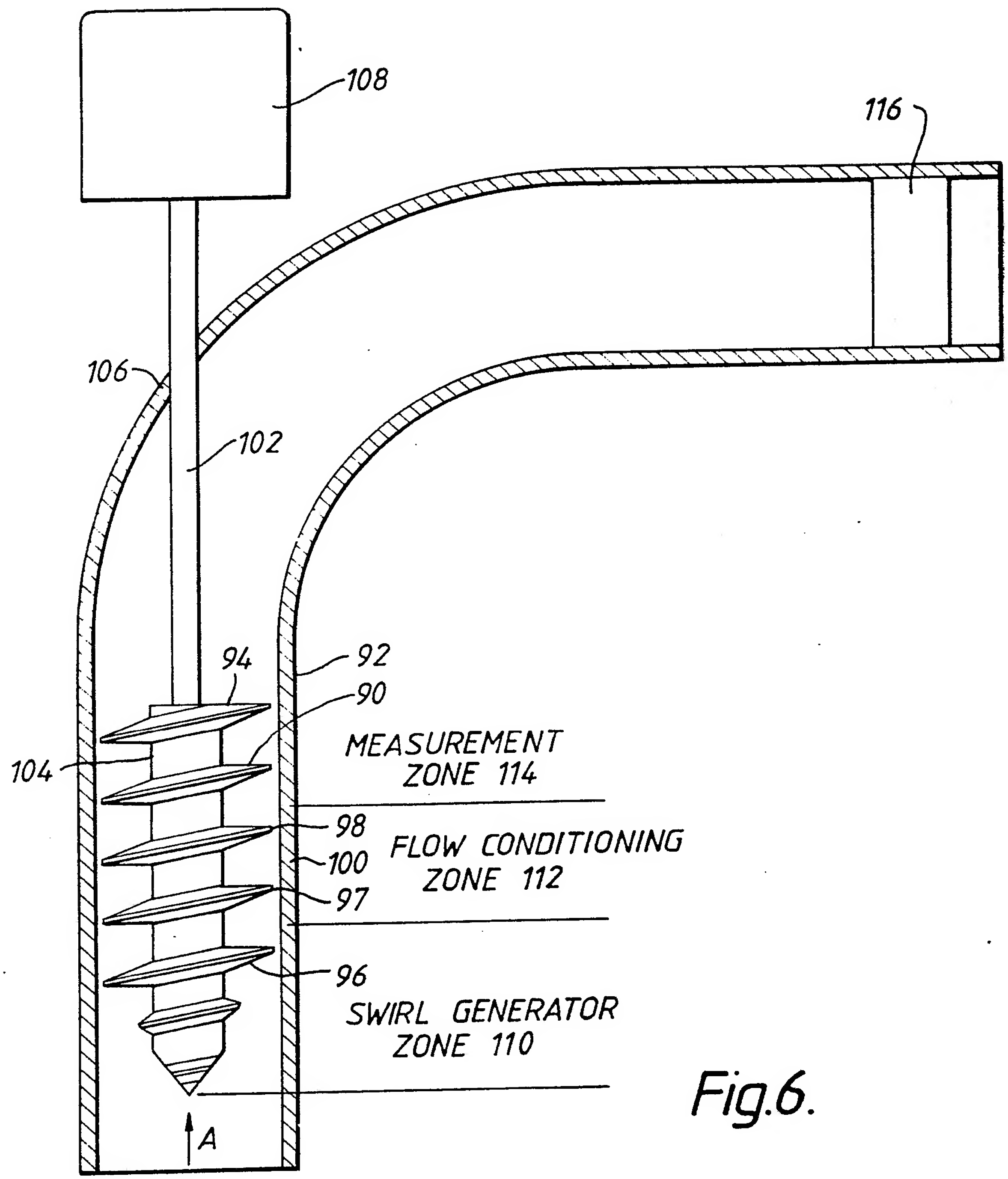
Fig.5.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100
97
FLOW CONDITIONING
ZONE 112
96
SWIRL GENERATOR
ZONE 110
A

Fig.6.

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 90/01847

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC^5: G 01 F 1/32, 15/08, 1/74, 1/66

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC^5	G 01 F

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	GB, A, 2152213 (INSTITUT FRANCAIS DU PETROLE) 31 July 1985 see the whole document	1,15-17
Y		6
A		3,4,7,8,11, 12,18-21

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* Special categories of cited documents: [10]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
20th February 1991	15. 03. 91
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	Natalie Weinberg

Form PCT/ISA/210 (second sheet) (January 1985)

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. GB 9001847 SA 42281

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 12/03/91
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82